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Relationship between fluid loss variation and physical activity during official games in elite soccer players

Relaciones entre la variación de pérdida de líquidos y la actividad física durante partidos oficiales en jugadores de fútbol de élite

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Abstract

The aim of the present study was to analyse the relationships between fluid ingestion, changes in body mass and physical activity amongst elite soccer players. 32 elite French soccer players were divided into six playing positions: goalkeepers (GK), central defenders (CD), full backs (FB), central midfielders (CM), wide midfielders (WM) and forwards (FW) and participated in official friendly matches within two consecutive pre-season periods. Body mass changes and fluid ingestion were recorded before, during and just after the matches. Time-motion characteristics were also analysed. Players ingested 1.4±0.6 L of fluids during matches and lost 1.4±0.6 kg at the end of the games. WM lost more weight than GK, FB and FW ($p<0.05$) and CM lost more weight than GK ($p<0.05$). Furthermore, CD covered significantly less total distance, high (HI) and very high intensity running distance than all other playing positions excluding GK ($p<0.05$); and WM covered greater distances at HI than all other playing positions. No differences were found in fluid ingestion between playing positions. The results of this study indicate that sweat loss was significantly different when comparing across various playing positions. As a result, sweat lost may be more influenced by HI activity during a game than other physical activity within game scenarios. Therefore, players with the highest amount of HI activities during a match should even more pay attention to their rehydration.

Key words: performance; fatigue; drinking; dehydration; football; playing position.

Resumen

El objetivo del presente estudio consistió en analizar las relaciones entre la ingesta de líquidos, cambios en la composición corporal y en la actividad física en jugadores de élite. La muestra estaba compuesta por 32 jugadores franceses de élite divididos en seis posiciones de juego: porteros (P), defensas centrales (DC), laterales (L), mediocentros (M), Extremos (E) y delanteros (D). Se registraron en dos partidos amistosos jugados en la pretemporada. Los cambios en composición corporal y la ingesta de líquidos se realizaron antes, durante y después de los partidos. Los datos sobre rendimiento físico también fueron registrados. Los jugadores tomaron 1.4±0.6 L de líquidos durante los partidos y perdieron 1.4±0.6 L al terminar los mismos. Los E perdieron más peso que los P, L y D ($p<0.05$) y los M más que los P ($p<0.05$). Asimismo, los DC corrieron menos distancia total, a alta (HI) y muy alta intensidad que el resto de puestos de juego, con excepción de los P ($p<0.05$); y los E recorrieron más distancias a HI que los otros puestos de juego. No se encontraron diferencias sobre la ingesta de líquidos entre puestos de juego. Los resultados del estudio indican que la pérdida de líquidos por sudor fue diferente entre los puestos de juego. De modo que la pérdida de sudor pudo afectar la actividad a HI durante el partido por encima de otros parámetros físicos en los escenarios de competición. Por lo tanto, los jugadores con mayor actividad a HI en los partidos deberían tener una mayor atención a los aspectos de rehidratación.

Palabras clave: rendimiento; fatiga; hidratación; deshidratación; fútbol; puestos de juego.

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Introduction

Team sports such as soccer are played and trained for continuously throughout the year regardless of the variance of temperatures. Due to the fact that the majority of the elite European soccer leagues begin during the middle of the summer, as a result, the pre-season preparation phase is usually conducted within a (extremely) warm climate (Dellal, 2008). As part of the pre-season phase, players perform repetitive intensive physical and specific sessions in order to improve their overall technical, tactical and physical profiles (Saw, Main & Gastin, 2015) knowing that pre-season was considered as essential for the final ranking (Sawka & Montain, 2000). Within the excessive warm climates, sweat loss during physical exercise is suggested to be greater than cooler conditions (Lago-Penas & Sampaio, 2015). Mohr et al. (2010) reported a reduction more than 2% of body mass after a soccer match was correlated with a reduction of post-match physical performance. Also, top-players during the 2014 FIFA world cup seemed to modulate their activity pattern, covering less high-intensity running, when playing in hot and humid environment (Nassis, Brito, Dvorak, Chalabi, Racinais, 2015; Watanabe, Wicker, Yan, 2017). The increase of core temperature, the reduction of cerebral function, the elevation of heart rate and the increase of muscle glycogen utilization may explain the reduced physical performance within a hot environment (Maughan, 1999; Mohr, Krustrup & Bangsbo, 2005).

Effects of exercise-induced dehydration have been well reported within the literature by several authors since two decades (Broad, Burke, Cox, Heeley & Riley, 1996; Maughan & Shirreffs, 2012; Mohr & Krustrup, 2012) with its detrimental effects being suggested to be more important regarding aerobic performance when compared to strength (Barr, 1999). Since the characteristics of a soccer game include repetition of high intensity actions throughout the duration of a game (Bradley, Sheldon, Wooster, Olsen, Boanas & Krustrup, 2009), dehydration may have negative effects on soccer players' physical performance. Limited literature reviews have provided the effects of sweat loss on performance, however one study suggested that the fluid intake did not have any immediate effects on specific soccer test performance (Owen, Kehoe & Oliver, 2013). However, other studies have reported a positive effect of fluid intake on physical soccer tests (McGregor, Nicholas, Lakomy & Williams, 1999; Edwards, Mann, Marfel-Jones, Rankin, Noakes & Shillington, 2007) as well as highlighting a correlation between the reduction of performance on repeated sprint ability (RSA) test and fluid loss (Mohr & Krustrup, 2013). Finally, during official games, Ozgünen et al. (2010) showed that semi-professional players covered less total distance during the second half in higher ambient temperature and relative humidity. However, to date, there is still a lack in the available literature on the role of dehydration on physical activity during official games in elite professional soccer players. Additionally, dehydration levels may differ depending on the playing position played in line with their variance of physical outputs within competitive match play (Dellal, Wong, Moalla & Chamari, 2010).

Investigations have shown within cool conditions (~6-8°C, ~50-60% of humidity), players lost on average ~1.68L during an English Premier League reserve official match (Maughan, Watson, Evans, Borad & Shirreffs, 2007) whereas within a warm environment (~34°C, ~64% of humidity), players lost ~3.1L (Kurdak, Shirreffs, Maughan, Ozgunen, Zeren, Korkmaz et al., 2010). In addition, the individual variability in the quantity of fluid loss remained important in these studies and this may be related to the difference in dehydration in regards to players' playing position.

To our knowledge, no study has analysed the acute body mass changes of professional soccer players during and just-after pre-season matches in hot climatic conditions according to the playing positions. Moreover, no study has compared body mass changes and fluid intakes with respect to playing positions, and analysed correlations between players' activity and theses variables. In this context, the aims of the present study was to analyse the effects of pre-season elite professional European soccer matches in hot climatic conditions, on body mass and fluid variations, to compare variations between playing positions and to analyse correlations with players' physical activity. It may be hypothesised that fluid intakes and fluid loss would be correlated with playing positions and physical activity during the game.

Materials and Methods

During soccer matches, elite players were analysed with their fluid intake and their body mass variations from the beginning to the end of the games. Physical activity was also analysed in order to correlate it with the two variables above. Players playing positions were independent variables and fluid intake, body mass and the distance covered at different intensities were the dependent variables.

Subjects

Thirty-two male elite soccer players (age: 23.4±3.1 years; height: 174.1±3.1 cm; body mass: 73.5±5.2 kg) of the same French first league team participated in this study. They were classified into six different playing positions: goalkeepers (GK; n=3), central defenders (CD; n=7), full backs (FB; n=5), central midfielders (CM; n=8), wide midfielders (WM; n=3) and forwards (FW, n=6) for a total of 61 individual match-activities analysed. The study was explained to all players and they all gave their written consent. The study was approved by the ethics committee certified by the National Council of Health and was conducted according to the principles of the declaration of Helsinki.

Procedures

The measurements have been done during six matches of the two last weeks of the six weeks pre-season preparation over two consecutive seasons. The weather conditions are detailed in Table 1. Players were weighted in underwear using a 0.1 kg precise portable digital scale (Omron HN-288, Healthcare Europe B.V., Hoofddorp, Netherlands) just before each collective warm-up and immediately after each match (three minutes after the match or the substitution). Before the first weighting, players were asked to empty their bladder. Players who did not play at least 60 minutes of the match were excluded from the study because lower duration should not be enough to have an impact and due to the fact that the status of the starter players were favoured. From the beginning of collective warm-up until the end of the match, they all had their own controlled individual bottles in order to measure individual fluid intake while no food has been given. All the weighting measures were performed twice and the coefficient of variation (CV) was ~1%. The urine outputs were not measured in the protocol. By adding the quantity of fluid intakes and the body mass loss, we obtained what we called the estimated total sweat loss, inspired from the equation used by King et al. (2008) but without estimating the potential quantity of substrate oxidation, respiratory water loss, and metabolic water.

Table I. Weather conditions of professional pre-season soccer matches

	Match 1	Match 2	Match 3	Match 4	Match 5	Match 6	Mean
Hour	4pm	7.45pm	8.45pm	8pm	6.15pm	6.15pm	-
Temperature	27.5°C	18.0°C	23.5°C	32.0°C	19.0°C	21.0°C	23.5°C
Humidity	37%	83%	78%	65%	82%	82%	71%

Players' activity during matches was recorded using a portable global positioned system (GPS) device operating at a sampling frequency of 15Hz (GPSports SPI Elite, Canberra, Australia). The system uses signals from at least three earth-orbiting satellites to determine the position and calculate movement speeds and distances. Units were placed in a harness on the player's upper back. After recording, the data were downloaded to a PC and analysed using the software package. The data analysed were the total distance covered (TDC), the distance covered in the two following speed categories: high 16-23 km·h-1 (HI) and very high >23 km·h-1 (VHI) intensities according to the different speed categories proposed by the available research (Dellal, Chamari, Wong, Ahmaidi, Keller, Barros, et al., 2011).

Statistical analysis

All data were presented as mean ± standard deviation and inter-individual coefficient (CV) of variation was calculated. Data were tested for normality, and then a one-way analysis of variance (ANOVA) was used to evaluate differences between playing positions in body mass changes, fluid intakes, total estimated loss and physical activity. In case significant differences were found, a Tukey *post hoc* test was used in order to identify points of differences. Cohen's d effect sizes (ES) for identified statistical differences were determined. When calculating ES, pooled SD was applied due to the absence of a control group. ES with values of 0.2, 0.5 and 0.8 were considered to represent small, medium and large differences, respectively (Cohen, 1998). Correlation analyses between variables were assessed using Pearson's product-moment correlation test. All the statistical analysis were realised using Statistica 12.0 (Stat-Soft, Tulsa, USA) and significance was accepted when a p-value of less than 0.05 was found.

Results

Players body mass was 76.6±7.7 kg pre- and 75.2±7.6 kg post-matches. The differences between body mass were found significant ($p<0.05$) and CV went from 4 to 10%. Total fluid intake was 1.4±0.6 L for an estimated total of lost sweat of 2.9 ± 0.7 kg.

Significant differences in body mass changes were found between playing positions. WM lost more relative mass than GK, FB and FW ($p<0.05$) and CM lost more mass than GK ($p<0.05$) (ES=0.48). No significant differences between playing positions were found in fluid intake quantity and in total estimated loss. Results of body mass and fluids intake are presented in Table 2.

Significant differences between playing positions were found in physical activity (Table 3): CD covered lower total distance (ES=0.60), HI (ES=0.70) and VHI (ES=0.76) distance than other playing positions (p<0.05) and FW covered greater VHI distance than CM (p<0.05).

No significant correlations were found between physical activity and both fluid intakes and body mass changes (p>0.05).

Table II. Changes in body mass of elite soccer players, divided into six playing positions, during pre-season matches in hot conditions.

Playing positions	n	BM before (kg)	CV	BM after (kg)	CV	Weight loss (kg)	CV	Weight loss (%)	CV	Intakes (L)	CV	Intakes (%)	CV	Real estimated loss (kg)	CV
GK	6	80.57 [cde] (3.80)	0.05	79.58 * (3.89)	0.05	0.98 (0.40)	0.41	1.23% (0.52%)	0.42	1.17 (0.29)	0.25	1.41% (0.25%)	0.18	2.37 (0.06)	0.02
CD	13	85.40 [cdef] (7.38)	0.09	83.80 * (7.40)	0.09	1.60 [~a] (0.67)	0.42	1.89% (0.85%)	0.45	1.54 (0.71)	0.46	1.80% (0.81%)	0.45	3.14 (0.56)	0.18
FB	9	73.07 (6.00)	0.08	71.93 * (5.76)	0.08	1.13 (0.29)	0.26	1.54% (0.28%)	0.18	1.42 (0.70)	0.49	1.92% (0.85%)	0.44	2.58 (0.99)	0.38
CM	18	71.51 (6.27)	0.09	69.98 * (5.99)	0.09	1.53 (0.74)	0.49	2.11% [a] (1.02%)	0.48	1.45 (0.46)	0.32	2.02% (0.55%)	0.27	2.98 (0.75)	0.25
WM	4	72.68 (4.25)	0.06	70.70 * (4.04)	0.06	1.98 [~acf] (0.56)	0.28	2.71% [acf] (0.69%)	0.26	0.75 (0.20)	0.27	1.03% (0.26%)	0.25	2.73 (0.76)	0.28
FW	11	76.57 [d] (3.46)	0.05	75.31 * (3.19)	0.04	1.26 (0.50)	0.39	1.64% (0.62%)	0.38	1.41 (0.48)	0.34	1.83% (0.60%)	0.33	2.67 (0.81)	0.30
All players	61	76.58 (7.74)	0.10	75.17 * (7.64)	0.10	1.41 (0.63)	0.45	1.85% (0.83%)	0.45	1.39 (0.56)	0.40	1.81% (0.67%)	0.37	2.86 (0.74)	0.26

GK: goalkeepers; CD: central defenders; FB: fullbacks; CM: central midfielders; WM: wide midfielders; FW: forwards; BM: body mass; CV: inter-individual coefficient of variation; NR: non-recorded. a, b, c, d, e, f: respectively higher than GK, CD, FB, CM, WM and FW (p<0.05); ~a: higher than GK (p=0.06); * significantly lower than BM before (p<0.05)

Table III. Match activity of elite soccer players during pre-season matches in hot conditions.

Playing positions	n=	TDC ($m.min^{-1}$)	CV	HI ($m.min^{-1}$)	CV	VHI ($m.min^{-1}$)	CV
GK	6	NR NR	NR	NR NR	NR	NR NR	NR
CD	13	96.66 (10.13)	0.10	8.12 (3.50)	0.43	1.03 (0.60)	0.59
FB	9	111.36 ^{b} (11.27)	0.10	12.52 ^{b} (3.24)	0.26	2.94 ^{b} (1.63)	0.55
CM	18	114.61 ^{b} (12.80)	0.11	12.93 ^{b} (3.05)	0.24	1.92 ^{b} (1.03)	0.54
WM	4	113.66 ^{b} (11.96)	0.11	17.14 ^{b} (8.30)	0.48	2.76 ^{b} (0.85)	0.31
FW	11	111.87 ^{b} (15.93)	0.14	14.67 ^{b} (4.69)	0.32	3.28 ^{b,d} (1.54)	0.47
All players	61	109.14 (14.21)	0.13	12.37 (4.77)	0.39	2.18 (1.40)	0.64

GK: goalkeepers; CD: central defenders; FB: fullbacks; CM: central midfielders; WM: wide midfielders; FW: forwards; TDC: total distance covered; HI: high intensity; VHI: very high intensity; CV: inter-individual coefficient of variation; NR: non-recorded.
a, b, c, d, e, f: respectively higher than GK, CD, FB, CM, WM and FW ($p<0.05$); ~a: higher than GK ($p=0.06$).

Discussion

The aim of the present study was to analyse changes in elite European soccer players' body mass after pre-season matches in hot climatic conditions. A statistical significant body mass lost was observed despite players' ingested fluid during matches (Table 2). By adding changes in body mass with total fluid intake, it was calculated an estimation of total sweat lost, without estimating the potential quantity of substrate oxidation, respiratory water loss, and metabolic water (King, Cooke, Carroll & O'Hara, 2008). This total estimated fluid loss corresponded to a 3.7±0.9% of body mass reduction, but due to the fluid intake, only 1.9±0.8% of body mass was effectively lost. These results were in accordance with the study of Mohr et al. (2010) as well as corresponding to most of the studies in elite soccer match play, in most environmental conditions (Edwards & Noakes, 2009). Furthermore, the present results were also in line with values observed amongst professional soccer players during training sessions in the heat (Maughan, Merson, Broad & Shirreffs, 2004; Shirreffs, Aragon-Vargas, Chamorro, Maughan, Seratosa & Zachwieja, 2005).

Kurdak et al. (2010) reported that soccer players lost 3.1L of sweat and replaced 55% (or 1.7L) in warm climates whereas in cool conditions, Maughan et al. (2004) reported a loss of 1.68L and ingestion of 0.84L (50%). Within this particular study it was found that a total loss of 2.9L for 1.4L of fluid intake (48%) was prevalent. Overall, the combined results from these investigations suggest that the warmer the climate, the more soccer players lose sweat (Sawka & Montain, 2000).

To our knowledge, no previous study evaluated the differences in body mass changes and fluid ingestion between playing positions of soccer players during elite soccer games. The analysis of physical activity showed that CD covered lower total distance, HI and VHI distance than other playing positions. It was also found that FW covered greater VHI distance than CM ($p<0.05$). Results were similar with those from Dellal et al. (2010) although the present study had less match activity to analyse (n=3540 vs. 61). They found that FW, WM and CM covered a greater total distance than others playing positions, that WM covered greater distances and that CD and FB lower HI distances (21-24 km·h-1 in their study), and that FW covered more distances and CD less distances than others playing positions in sprinting activity (>24 km·h-1 in their study). The data collected in the present study seemed to correspond with the French 1st division league normative ranges observed revealing that players who usually covered greater distance during a match (Dellal, Wong, Moalla & Chamari, 2010) were those who lost the highest body mass. These findings are in line with previous statements suggesting that the reason why GK lose less weight than other playing positions is possibly due to the lesser distances covered in conjunction with the less physical aerobic work performed when compared to other players on the pitch (Di Salvo, Benito, Calderon, Di Salvo & Pigozzi, 2008). The concomitance between the higher HI covered distance and the higher body mass lost by WM (vs. FB and FW) suggested that the HI distance during the match could impact the sweat lost in soccer players. In this context, Duffield et al. (2012) have recently shown that professional Australian football players lost more water when practising high- vs. low- intensity training sessions. In rugby and US football, it was observed that players lost more water while training in high intensity aerobic sessions than in resistance training sessions (Stofan, Osterberg, Horswill, Lacamba, Eichner, Anderson et al., 2007; Cosgrove, Love, Brown, Baker, Howe & Black, 2014). All together, these results confirmed that water loss could depend on duration and nature of the physical activity. The present study suggests that the quantity of liquid loss during the soccer games was more related with the HI distances than the total or the VHI running distances. More studies analysing physical activity and body mass changes in soccer players are needed to confirm the present results, however, it should be acknowledge that the amount of physical activity is not the only factor that may explain changes in body mass at the end of a game. Our results revealed high CV (from 18 to 48%) showing important differences between players within the same playing positions. Explanations for these results could be the individual metabolism, the aerobic fitness and the level of heat acclimation, which all have an impact on body composition changes during physical activity (Coyle, 2004).

No significant differences between playing positions were found significant concerning fluid intakes although we hypothesized that players who covered more distances during the game would intake more fluids. Surprisingly, CD ingested more fluid than other players (1.5 L) while they covered the lower total, HI and VHI distances. However, they did not ingest the highest quantity of fluid according to the body mass ratio (1.8 %). This variable might not mainly depend on physical activity on the pitch, but probably more on the body mass, on the individual thirst sensation and on the individual ability to hydrate during breaks and half time. Furthermore, this study has confirmed amongst elite first French league players that there are no significant correlations between running distance and fluid ingestion or body mass changes, regardless of playing positions. Mohr et al. (2010) did not find correlation between fluid loss and sprinting activity (>22 km·h-1 for them) of soccer players from second and third Spanish division, during a simulated game. Interestingly, however, they found a correlation (r=0.73) between fluid loss and a repeating sprint ability test that players performed after the game. Similarly, Edwards et al. (2007) found a significant incidence of fluid intake on a post-match intermittent soccer test. All these data confirm that the induced soccer match dehydration decreases performance in specific soccer tests. Furthermore, if match play dehydration would not affect players' activity, hydration strategies would remain determinant for the recovery process (Nedelec, McCall, Carling, Legall, Berthoin & Dupont, 2012). More investigations are needed in order to analyse real impact of hydration, or dehydration, on official match performance and to determine effects of hydration on recovery kinetics.

We acknowledge that the statistical procedure that we used may represent a methodological limitation. Our population was composed from a group of professional soccer players during its pre-season preparation period over two consecutive seasons. Although some players were observed twice, we considered our population as independent samples. Indeed, for these subjects, because the matches were far apart from one to another, the characteristics of a player from a year to another was likely different. Furthermore, the quality of sweat was not measured in this study whereas it is well known that players lose water and electrolytes such as sodium, potassium or magnesium during activity (Shirreffs, Sawka & Stone, 2006).

Conclusion

It can be concluded from this particular investigation that soccer players covering more HI distance during a soccer game would be the same players that lost more body fluid within warm climate conditions. Thus, the individualized hydration strategy (during breaks, half-time and after a soccer match) should be organized considering these players as needing more fluid as reported from the uptake of the fluids by the player.

Players' sweat loss was approximately 2% of body weight despite the mean average 1.4L fluids taken during matches. This highlights the importance of hydration or refuelling strategies during match play within warm climates. Hydrating during half time or during large duration breaks induced within the game (e.g., injury, disciplinary issues, goals) is likely to not be sufficient enough to rehydrate. Within these conditions, breaks during the two periods should be systematically anticipated and planned as part of an organizational structure (e.g. governing bodies, referees) in order to allow all players and officials to intake some fluid, especially when outside climatic conditions are hot. Based on the fact that players lose more electrolytes than water, player hydration strategies should include individualised sport drinks with potentially higher concentration of electrolytes based on their physical profiles. Additionally, CDs and GKs show a reduced TDC when compared to other positions within match activity profiles. This may add justifications to question individualised carbohydrate and supplementation intake vs. other higher energy positions. The individualised nature of performance related sport drinks should be further researched in order to understand better which positions may benefit from which specific supplements.

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